National Aeronautics and
Space Administration

GRADES K–12

Supplemental Space Shuttle Tire Lessons

structures and materials

Aeronautics
Research
Mission
Directorate

Museum in a BOX Series

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Supplemental Space Shuttle Tire Math Activity 1

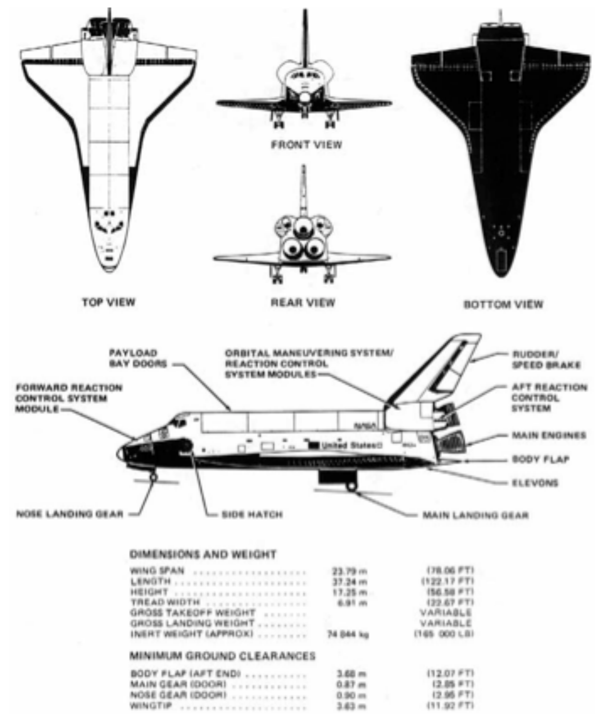
Spare Parts for the Space Shuttle

GRADES **K–12**

Background

NASA's Space Shuttle has six tires used for landing. The four main landing gear tires are mounted in pairs on the rear wheel assemblies. These wheel assemblies are attached to the two main landing struts at the rear of the Shuttle. Each of the four main landing gear tires is used for one flight. The front two tires, again mounted as a pair, are attached to the nose landing gear strut and are used for two Shuttle landings. The four rear main landing gear tires hit the ground first, which causes them to wear out sooner. Because the main tires are on the ground longer than the front landing gear tires and because they take the brunt of the mass and force of the Space Shuttle landing (the Shuttle lands at speeds of up to 250 miles per hour [mph]), main and front tires have different needs. While both types of tires have very little tread to reduce the mass of the tires, these tires are also different sizes, since a larger tire is not needed in the front of the Shuttle. This is similar to tire-size-ratio needs for other aircraft as well.

(photo from *http://www.nasaimages.org*)



(photo from *http://www.history.nasa.gov /SP-4225/diagrams/shuttle/shuttle-diagram-1.htm*)

Shuttle Tire Facts

Surprisingly, a Space Shuttle tire is not much larger than a truck tire, but a main landing gear tire can carry three times the load of a Boeing 747 tire or the entire starting lineup of a NASCAR race—40 race cars—all hitting the pavement at up to 250 miles per hour.

- Four main landing gear tires: 44.5 × 16.0-21, 34 ply, rated at 263 mph.
- Two nose landing gear tires: 32 × 8.8, 20 ply, rated at 250 mph.
- Space Shuttle tires are filled with nitrogen (as are most aircraft tires) due to its stability at different altitudes and temperatures. Due to extremely heavy loads, these bias ply tires are inflated to 340 pounds per square inch (psi) for the main landing gear and 300 psi for the nose landing gear.

- Shuttle tires go from in excess of –40 degrees Fahrenheit (–40 degrees Celsius) in space to +130 degrees Fahrenheit (54.4 degrees Celsius) on landing in a matter of minutes.

- Weight: Since weight is of extreme importance, the tires are made with a minimum amount of tread to conserve weight, allowing for larger payloads. A few pounds may not seem to make much difference, but when you add up all of the ways to decrease weight throughout the Shuttle, it can have a significant impact.

Size/Dimension	44.5 × 16.0-21 (main landing gear)
Outside Diameter	44.9 inches
Section Width	16 inches
Wheel Rim Diameter	21 inches
Approximate Weight	205 pounds (on Earth)
Max. Inflation Pressure	340 psi
Max. Operation Load	142,000 pounds (on Earth)
Max. Speed	259 mph
Load Per Pound of Tire	695 pounds

While most of us have focused on watching the Space Shuttle launch and land, a group of scientists and engineers have been responsible for determining how many spare parts had to be available to keep Shuttle missions running smoothly. In all, they had to think about 250,000 repairable and nonrepairable parts. This included making sure there were enough tires for each Shuttle flight.

Logistics engineers Seth Berkowitz, Randy Greeson, and Marcia Groh-Hammond at NASA's Kennedy Space Center explain a bit about their jobs:

> There are certain things in life that we take for granted. For instance, we never give much thought to it, but we keep spares of basic household products. Most households contain spare paper towels, toilet paper, soap, shampoo, etc. How many and what types of items we buy to support our house is usually automatically calculated in our heads while going through the supermarket. We consider how often we consume an item, and how much it costs. Generally, the more expensive the item is the fewer spares we keep on hand. We are concerned about our budget. We know in most cases we can replenish that item when we need it; it is simply a matter of going to the store to pick it up. For instance, you are making a cake and run out of eggs. You go to the store and buy what you need. There is no waiting for the hen to lay the eggs and the eggs to be delivered from the farm. It's a short delay, a slight inconvenience.
>
> Now imagine not being able to go to the corner grocery store and pick up what you need. On top of that, you have to wait weeks, months, maybe longer, once you decide you need it. The items you are buying cost $1,000, $10,000, $100,000, or more than $1,000,000. Deciding what you need and when to buy it is not as automatic as buying ordinary household items. This is the dilemma that faces the Space Shuttle Logistics Office.
>
> One of the keys to successfully launching Shuttles on-time and within budget involves hardware availability. The availability of the hardware must not impose a constraint on the processing of the Shuttles. The Nation cannot afford to have an expensive national resource such as the Shuttle waiting on the launch pad for a part. The methods used to determine spare requirements for the Shuttle must be effective and efficient in terms of adequately identifying the required spares without incurring excessive program costs.

Procedure

In the following math problems, you are going to take on the role of a logistics engineer at NASA's Kennedy Space Center in Florida. Your job will be to make sure that you have enough Space Shuttle tires available for Shuttle flights. You should also plan on having an extra set of tires on hand in case of unexpected events, such as an additional flight and/or problems with a tire(s). Keep in mind that each tire costs over $5,560, so you do not want to have too many tires. However, since it takes 9 months to have tires delivered from the time you order them from Michelin, a mistake of having too few tires would delay a Shuttle flight at least 9 months.

Tire information

Total number of tires per Space Shuttle: 6

Main landing gear tires per Shuttle: 4

Usage limit: 1 flight

Front landing gear tires per Shuttle: 2

Usage limit: 2 flights

Lead time on tire order: 9 months

Cost, per tire: $5,560

Problem 1: How Many Tires?

In 2009, there are 5 planned Space Shuttle launches. Beginning in 2008, as logistics engineers, you have to place an order for Shuttle tires for 2009. However, you also have to account for existing, usable tires. The final Shuttle flight of 2008 used a completely new set of tires. Using the information above, calculate the number of tires needed for Space Shuttle flights in 2009. In addition, make sure to order one complete set of extra tires in case they are needed. Next, calculate the cost for the tires. Finally, decide when your order needs to be placed in order to ensure that tires are available for a February 2009 launch. (Show your work.)

Order Form:	Number of Tires	Cost of Tires	Total Cost
Existing inventory of usable main landing gear tires			
Main landing gear tires needed			
Spare main landing gear tires needed			
Existing inventory of usable front landing gear tires			
Front landing gear tires needed			
Spare front landing gear tires needed			
		TOTAL ORDER COST:	
		Last day to place order:	

Problem 2: Changing Your Order

NASA needs to get more parts to the International Space Station and needs to capture a failing satellite, so they add two more flights to their 2009 schedule. If they notify you of this change before you place your original order, what is your edited order? (Show your work.)

Order Form:	Number of Tires	Cost of Tires	Total Cost
Existing inventory of usable main landing gear tires			
Main landing gear tires needed			
Spare main landing gear tires needed			
Existing inventory of usable front landing gear tires			
Front landing gear tires needed			
Spare front landing gear tires needed			
		TOTAL ORDER COST:	
		Last day to place order:	

Problem 3: Changing Your Order, Part Two

In January of 2009, long after you placed your updated order, one front landing gear tire was punctured during preparation for a Shuttle launch. In addition, there is a need for an additional repair mission in May of 2009. (*The expanded 2009 Shuttle launch schedule is as follows: February 4, March 15, April 20, May 11, July 15, August 28, October 1, and November 16.) Based on the number of tires available, can this be done? Explain your answer.

*The actual launch schedule for 2009 included the following dates: March 15, May 11, July 15, August 28, and November 16. The additional dates were added for this activity only.

Adapted from "LTA 1: Kennedy Space Center: Spare Parts for the Space Shuttle," NASA-AMATYC-NSF Project Coalition, *http://cctc.commnet.edu/lta/lta1/index.pdf*.

Supplemental Space Shuttle Tire Math Activity 1

Spare Parts for the Space Shuttle

GRADES **5–12** Answer Key

Procedure

In the following math problems, you are going to take on the role of a logistics engineer at NASA's Kennedy Space Center in Florida. Your job will be to make sure that you have enough Space Shuttle tires available for Shuttle flights. You should also plan on having an extra set of tires on hand in case of unexpected events, such as an additional flight and/or problems with a tire(s). Keep in mind that each tire costs over $5,560, so you do not want to have too many tires. However, since it takes 9 months to have tires delivered from the time you order them from Michelin, a mistake of having too few tires would delay a Shuttle flight at least 9 months.

Tire information

Total number of tires per Space Shuttle: 6

Main landing gear tires per Shuttle: 4

Usage limit: 1 flight

Front landing gear tires per Shuttle: 2

Usage limit: 2 flights

Lead time on tire order: 9 months

Cost, per tire: $5,560

Problem 1: How Many Tires?

In 2009, there are 5 planned Space Shuttle launches. Beginning in 2008, as logistics engineers, you have to place an order for Shuttle tires for 2009. However, you also have to account for existing, usable tires. The final Shuttle flight of 2008 used a completely new set of tires. Using the information above, calculate the number of tires needed for Space Shuttle flights in 2009. In addition, make sure to order one complete set of extra tires in case they are needed. Next, calculate the cost for the tires. Finally, decide when your order needs to be placed in order to ensure that tires are available for a February 2009 launch. (Show your work.)

Order Form:	Number of Tires	Cost of Tires	Total Cost
Existing inventory of usable main landing gear tires	0	n/a	n/a
Main landing gear tires needed	20 (5 sets of 4 tires)	$5,560	$111,200
Spare main landing gear tires needed	4 (one set)	$5,560	$22,240
Existing inventory of usable front landing gear tires	2 (one more use)	$5,560	n/a
Front landing gear tires needed	4 (2 sets)	$5,560	$22,240
Spare front landing gear tires needed	2 (one set)	$5,560	$11,120
		TOTAL ORDER COST:	$166,800
		Last day to place order:	April 30, 2008

Problem 2: Changing Your Order

NASA needs to get more parts to the International Space Station and needs to capture a failing satellite, so they add two more flights to their 2009 schedule. If they notify you of this change before you place your original order, what is your edited order? (Show your work.)

Order Form:	Number of Tires	Cost of Tires	Total Cost
Existing inventory of usable main landing gear tires	0	n/a	n/a
Main landing gear tires needed	28 (7 sets)	$5,560	$155,680
Spare main landing gear tires needed	4 (one set)	$5,560	$22,240
Existing inventory of usable front landing gear tires	2 (one more use)	$5,560	n/a
Front landing gear tires needed	6 (3 sets)	$5,560	$33,360
Spare front landing gear tires needed	2 (one set)	$5,560	$11,120
		TOTAL ORDER COST:	$222,400
		Last day to place order:	April 30, 2008

Problem 3: Changing Your Order, Part Two

In January of 2009, long after you placed your updated order, one front landing gear tire was punctured during preparation for a Shuttle launch. In addition, there is a need for an additional repair mission in May of 2009. (*The expanded 2009 Shuttle launch schedule is as follows: February 4, March 15, April 20, May 11, July 15, August 28, October 1, and November 16.) Based on the number of tires available, can this be done? Explain your answer.

Answers will vary, but this could be done if the spare tires were used and there were no more tire punctures. New tires would have to be ordered in January 2009 to replace the spare tires and the punctured tire, as well as for the additional mission. (The repair mission for April 20 would use a set of tires scheduled to be used later in the year. As long as replacement tires arrived before the November 16 launch, the addition would be feasible.)

*The actual launch schedule for 2009 included the following dates: March 15, May 11, July 15, August 28, and November 16. The additional dates were added for this activity only.

Adapted from "LTA 1: Kennedy Space Center: Spare Parts for the Space Shuttle," NASA-AMATYC-NSF Project Coalition, *http://cctc.commnet.edu/lta/lta1/index.pdf.*

Supplemental Space Shuttle Tire Math Activity 2

Space Shuttle Tire Lessons

GRADES 5–12

Background

Surprisingly, a Space Shuttle tire is not much larger than a truck tire, but a main landing gear tire can carry three times the load of a Boeing 747 tire or the entire starting lineup of a NASCAR race—40 race cars—all hitting the pavement at up to 250 miles per hour. So how can a Shuttle tire accomplish that? The following math problems may help you compare the Space Shuttle tire to other tires.

Surface Area and Ratios

In this math problem, you are going to calculate the surface area of the sidewall of a bicycle tire, a car tire, and a Space Shuttle tire. If you have the tire sections from the "Museum in a Box" kit, you can try to make calculations based on your own measurements from those tire sections. However, exact measurements are difficult because the tire sections are small and the surfaces are curved. To help simplify measurements, the chart below lists a standard set of measurements that can be used (making the assumption, for this problem, that the tire sidewall surfaces are flat). Notice that certain measurements are given to you in millimeters (mm), some in centimeters (cm), and others in inches (in). Unfortunately, when tire specifications are given, both millimeters and inches are used, which means you will have to convert these numbers for your needs. If you need help determining diameters based on the tire specifications listed, refer to the main "Space Shuttle Tire" lessons, where a "Tire Basics" section can be found.

Tire Type	O.D. (outside diameter, in inches)	I.D. (inside diameter, in inches)	Inside Radius (in inches) r = D/2	Total Radius (inside radius + sidewall height, in inches)	Total Tire Area (in inches^2)	Inside Tire Area (in inches^2)	Tire Side-wall Area (in inches^2)
Bicycle (26 × 13/8)							
Car (P185/70R14)							
Space Shuttle (main landing gear tire: 44.5 × 16.0-21)	44.9 inches	21 inches					

Hint: to calculate sidewall area, you are basically calculating the area of a donut (subtracting the area inside the circle from the outer area of the circle).

Diameter: $D = 2r$ Radius: $r = D/2$

Area of a circle: $A = \pi r^2$

To convert from inches to millimeters: multiply the number of inches by 25.4

To convert from millimeters to inches: divide the number of millimeters by 25.4

Step one: Find the inside and outside diameters of each tire (in inches). For a bicycle tire, the first number listed on the tire specifications is the outside tire diameter (in inches). For a car tire, the number after the tire construction (in this case, the "R" refers to a *radial* tire) is the inside diameter (in inches). The Space Shuttle tire numbering is slightly different, so it is given to you on the chart (in inches).

The second piece of information you need for this problem is the *aspect ratio*, or the height of the sidewall as a percentage of the *section width*. For a car tire, the aspect ratio is the number found after the "/" (the number 70 in this case). The section width is the first number after the tire class designation (the "P" for this tire, which refers to "passenger car" class). Section width is given in mm. The sidewall height for this tire is 70 percent of the section width. For a bike tire, the sidewall height (given in inches), is the second number in the tire specifications (for the bike tire above, the sidewall height is 1 3/8").

Show your work, including a labeled drawing that shows the numbers you are using for each component of the problem.

Step two: Find the areas of the circle inside each tire and the total area of each tire. Refer to the formulas above for help in calculating the areas of each circle. Give measurements in $inches^2$. Again, show all work.

Step three: Find the area of each tire's sidewall. Subtract the inner tire area from the total tire area to find your answer. Give measurements in $inches^2$ and show all work.

Once you have the total contact area of each tire, write the ratio of sidewall areas, from bicycle tire to car tire to Space Shuttle tire. Using only the sidewall surface area of the tires, explain why Space Shuttle tires are able to safely land the Space Shuttle.

Supplemental Space Shuttle Tire Math Activity 2

Space Shuttle Tire Lessons

GRADES 5–12 Answer Key

Surface Area and Ratios

In this math problem, you are going to calculate the surface area of the sidewall of a bicycle tire, a car tire, and a Space Shuttle tire. If you have the tire sections from the "Museum in a Box" kit, you can try to make calculations based on your own measurements from those tire sections. However, exact measurements are difficult because the tire sections are small and the surfaces are curved. To help simplify measurements, the chart below lists a standard set of measurements that can be used (making the assumption, for this problem, that the tire sidewall surfaces are flat). Notice that certain measurements are given to you in millimeters (mm), some in centimeters (cm), and others in inches (in). Unfortunately, when tire specifications are given, both millimeters and inches are used, which means you will have to convert these numbers for your needs. If you need help determining diameters based on the tire specifications listed, refer to the main "Space Shuttle Tire" lessons, where a "Tire Basics" section can be found.

Tire Type	O.D. (outside diameter, in inches)	I.D. (inside diameter, in inches)	Inside Radius (in inches) r = D/2	Total Radius (inside radius + sidewall height, in inches)	Total Tire Area (in inches^2)	Inside Tire Area (in inches^2)	Tire Side-wall Area (in inches^2)
Bicycle (26 × 13/8)	26 inches (found in tire specifications)	23.25 inches	11.6 inches	13 inches	530.7 inches^2	514.5 inches^2	32.6 inches^2
Car (P185/70R14)	24.2 inches	14 inches	7 inches	12.1 inches	459.7 inches^2	153.9 inches^2	305.8 inches^2
Space Shuttle (main landing gear tire: 44.5 × 16.0-21)	44.9 inches	21 inches	10.5 inches	22.5 inches	6,330.3 inches^2	346.2 inches^2	5,983.8 inches^2

Hint: to calculate sidewall area, you are basically calculating the area of a donut (subtracting the area inside the circle from the outer area of the circle).

Answer Key

Diameter: $D = 2r$ Radius: $r = D/2$

Area of a circle: $A = \pi r^2$

To convert from inches to millimeters: multiply the number of inches by 25.4

To convert from millimeters to inches: divide the number of millimeters by 25.4

Step one: Find the inside and outside diameters of each tire (in inches). For a bicycle tire, the first number listed on the tire specifications is the outside tire diameter (in inches). For a car tire, the number after the tire construction (in this case, the "R" refers to a *radial* tire) is the inside diameter (in inches). The Space Shuttle tire numbering is slightly different, so it is given to you on the chart (in inches).

The second piece of information you need for this problem is the *aspect ratio*, or the height of the sidewall as a percentage of the *section width*. For a car tire, the aspect ratio is the number found after the "/" (the number 70 in this case). The section width is the first number after the tire class designation (the "P" for this tire, which refers to "passenger car" class). Section width is given in mm. The sidewall height for this tire is 70 percent of the section width. For a bike tire, the sidewall height (given in inches), is the second number in the tire specifications (for the bike tire above, the sidewall height is 1 3/8").

Show your work, including a labeled drawing that shows the numbers you are using for each component of the problem.

Inside diameter of bicycle tire: 26 – 1.375 (3/8 converted) – 1.375 = 23.25 inches (when finding the inside diameter, remember that there are two sidewalls to figure into this)
Inside radius of bicycle tire: 23.25 ÷ 2 = 11.6 inches
Total bicycle tire radius: 26 ÷ 2 = 13 inches

Inside radius of car tire: 14 ÷ 2 = 7 inches
Outside diameter of car tire: sidewall height = 70% of section width (185 mm) = 185 × 0.70 = 130 mm
130 mm ÷ 25.4 (mm to inch conversion) = 5.1 inches
7 inches (inside radius) + 5.1 inches (sidewall height) = 12.1 inches (total radius) × 2 (to find diameter) = 24.2 inches

Shuttle tire sidewall height: 44.9 inches – 21 inches = 23.9 inches ÷ 2 (two sidewalls in total diameter) = 12 inches
Total Shuttle tire radius: 44.9 ÷ 2 = 22.5 inches

Step two: Find the areas of the circle inside each tire and the total area of each tire. Refer to the formulas above for help in calculating the areas of each circle. Give measurements in inches^2. Again, show all work.

Total bicycle tire area: $13^2 \times 3.14$ (π) = 530.7 inches^2
Inside bicycle tire area: $11.6^2 \times 3.14$ (π) = 422.5 inches^2

Total car tire area: $12.1^2 \times 3.14$ (π) = 459.7 inches^2
Inside car tire area: $7^2 \times 3.14$ (π) = 153.9 inches^2

Total Shuttle tire area: $44.9^2 \times 3.14$ (π) = 6,330.3 inches^2
Inside Shuttle tire area: $10.5^2 \times 3.14$ (π) = 346.2 inches^2

Supplemental Space Shuttle Tire Math Activity 2

Answer Key

Step three: Find the area of each tire's sidewall. Subtract the inner tire area from the total tire area to find your answer. Give measurements in $inches^2$ and show all work.

Bicycle tire sidewall area: 530.7 – 422.5 = 108.2 $inches^2$

Car tire sidewall area: 459.7 – 153.9 = 305.8 $inches^2$

Space Shuttle tire sidewall area: 6,330 – 346.2 = 5,983.8 $inches^2$

Once you have the total contact area of each tire, write the ratio of sidewall areas, from bicycle tire to car tire to Space Shuttle tire. Using only the sidewall surface area of the tires, explain why Space Shuttle tires are able to safely land the Space Shuttle.

32.6 : 305.8 : 5,983.8

Answers will vary on the explanation, but looking at the ratios of sidewall area, students should be able to point out that car tires are almost 10 times the surface area of the bike tires, which helps car tires carry more weight. Likewise, Shuttle tire sidewall area is more than 19 times the car tire sidewall area, making Shuttle tires that much stronger.

SPACE SHUTTLE TIRES LESSONS: NATIONAL SCIENCE STANDARDS

K–12

SCIENCE AS INQUIRY
All students should develop
- Abilities necessary to do scientific inquiry

PHYSICAL SCIENCE
All students should develop an understanding of
- Properties of objects and materials

SCIENCE AND TECHNOLOGY
All students should develop
- Abilities of technological design
- Understandings about science and technology

HISTORY OF NATURE AND SCIENCE
All students should develop an understanding of
- Science as a human endeavor

5–8

SCIENCE AS INQUIRY
All students should develop
- Abilities necessary to do scientific inquiry

PHYSICAL SCIENCE
All students should develop an understanding of
- Properties and changes of properties in matter
- Motions and forces

SCIENCE AND TECHNOLOGY
All students should develop
- Abilities of technological design
- Understandings about science and technology

PERSONAL AND SOCIAL PERSPECTIVES
All students should develop an understanding of
- Science and technology in society

HISTORY AND NATURE OF SCIENCE
All students should develop an understanding of
- Science as a human endeavor

9–12

UNIFYING CONCEPTS AND PROCESSES
All students should develop an understanding of
- Systems, order, and organization

SCIENCE AND TECHNOLOGY
All students should develop
- Understandings about science and technology

PERSONAL AND SOCIAL PERSPECTIVES
All students should develop an understanding of
- Science and technology in local, national, and global challenges
- Science as a human endeavor

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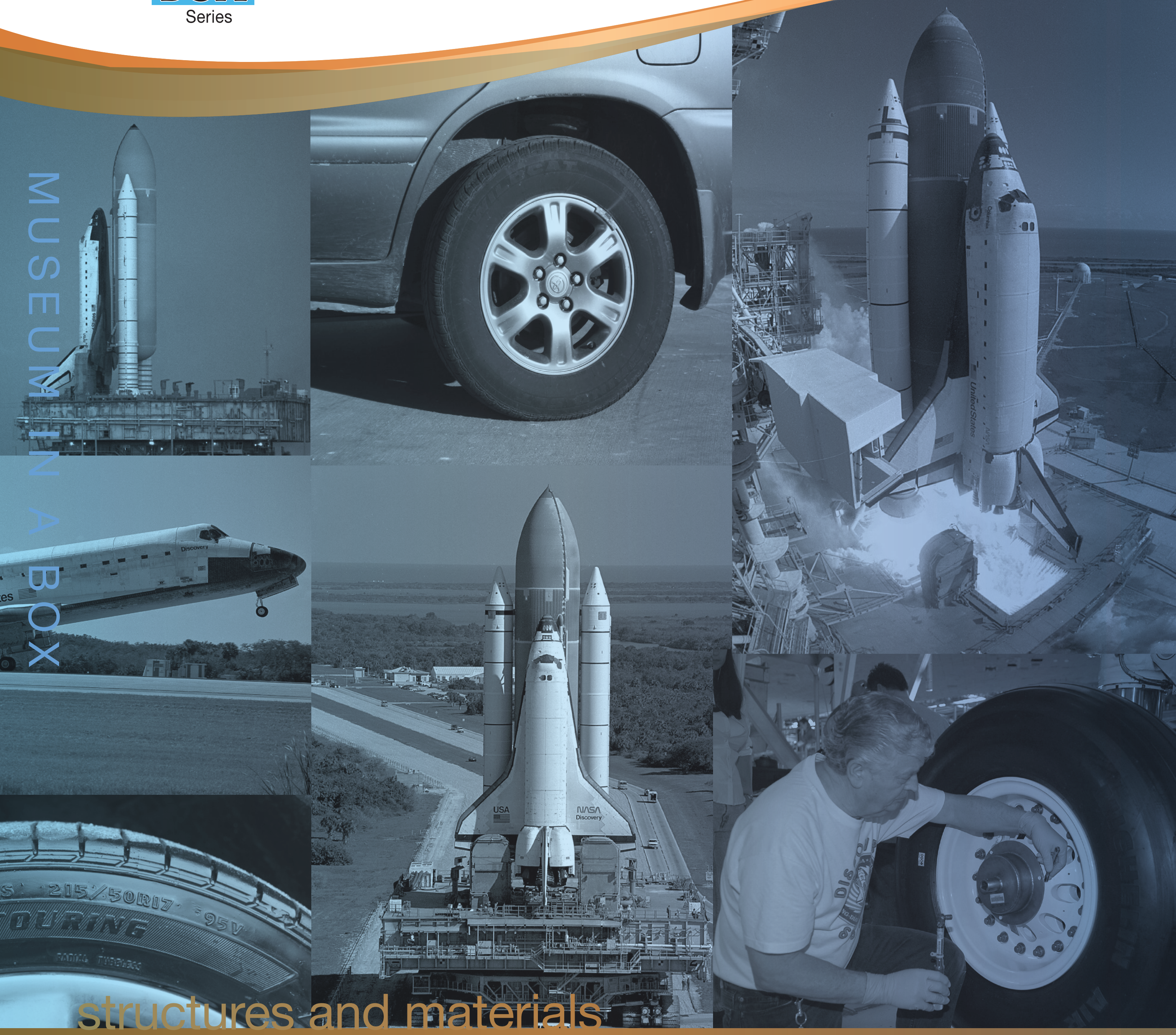


structures and materials

EP-2010-12-479-HQ

Supplemental Space Shuttle Tire Activity

Tire Permeability and Nitrogen-Filled Tires

GRADES **K–8** **5–12**

Lesson Objective

Students will learn about the structure and properties of matter by identifying different scents that diffuse through a semipermeable balloon membrane. Students will be able to identify abilities of technological design as they compare differing balloon membranes with Space Shuttle tires, which are also membranes.

Lesson Description

Students will try to identify the different extracts in each balloon. Since latex is more permeable than Mylar, students should be able to identify the extract scent that will escape from the latex balloons but should not be able to smell any of the extract within the Mylar balloons. Connections can then be made about some of the reasons NASA uses nitrogen, a larger gas molecule than other atmospheric gases, inside their Space Shuttle tires.

Materials

Several latex balloons and Mylar balloons (one of each balloon for each scent extract you have)
Scent extracts (can include vanilla extract, lemon extract, strawberry extract, etc.)
Plastic pipettes or eyedroppers (one per extract)
Air pump for balloons (optional)

Introduction

The background information above will provide information about how and why NASA has used nitrogen to inflate its Space Shuttle tires. This activity will show students how smaller-sized molecules such as scented extract can make their way through a porous solid. Latex, which is a liquid rubber, is much like the rubber used in Shuttle tires, car tires, and aircraft tires. Rubber is somewhat porous, which allows smaller molecules to make their way through the walls of that material. Since both pressurized tires and balloons have a higher internal than external pressure, gases within tires and balloons will try to reach equilibrium with outside gas pressure, causing diffusion to occur, if possible. There are several ways to prevent diffusion from occurring, and the objective of this lesson is to show students how that can be done. First, if gas molecules are too large to squeeze through the pores of the material membrane, then the gases will remain inside a balloon or tire. Nitrogen, for example, is a larger molecule than oxygen and other atmospheric gases including water vapor, so it doesn't make its way out of pressurized tires as easily. Another way to keep gases inside a membrane is to choose a material that has smaller pore sizes. Mylar balloons have much smaller pores than latex balloons, so this component of the activity shows that even tiny molecules such as vaporized extracts (or helium, as Mylar balloons are often used for), have trouble escaping. Mylar, in comparison to latex, is made from nylon sheeting that is coated with plastic and metallic materials. These different layers and materials make Mylar much less porous than latex.

Safety note: since latex balloons are used for this activity, warn students about the presence of latex, since some people are allergic to rubber and latex.

Procedure

Note: This lab needs to be set up before students enter the room so students cannot smell the extract scents before the activity.

Setup:

1. Using a plastic pipette or an eyedropper, add several drops of extract as deep into the balloon as possible (try not to get any of the extract on the balloon opening since even the smallest amount of extract is easy to smell).

2. Inflate and tie the balloon, again being careful not to get extract on your mouth or on the balloon pump.

3. Repeat steps one and two, using one latex balloon and one Mylar balloon for each scent. (To help you keep track of your balloons, you could use different colors for each scent. However, try not to be too obvious to students—don't use white or yellow for vanilla, red for strawberry, etc.)

4. Shake each balloon several times to help the extract vaporize within the balloon.

Activity

1. Introduce lesson background and discuss Shuttle tires and molecule size with students.

2. Explain that the balloons for this activity represent tires.

3. Ask students to complete the first part of their activity, which is to compare and contrast tires with both the latex balloons and the Mylar balloons (you may want to have an uninflated latex balloon and Mylar balloon for students to see and touch).

4. For the second part of the activity, have students move from balloon to balloon and try to identify each scent. It might be helpful to write a list of scents on the board before they begin.

5. When students have finished, discuss why the extract was able to diffuse through the latex balloon and not the Mylar balloon.

6. Review why Shuttle tires are inflated with nitrogen gas instead of regular air.

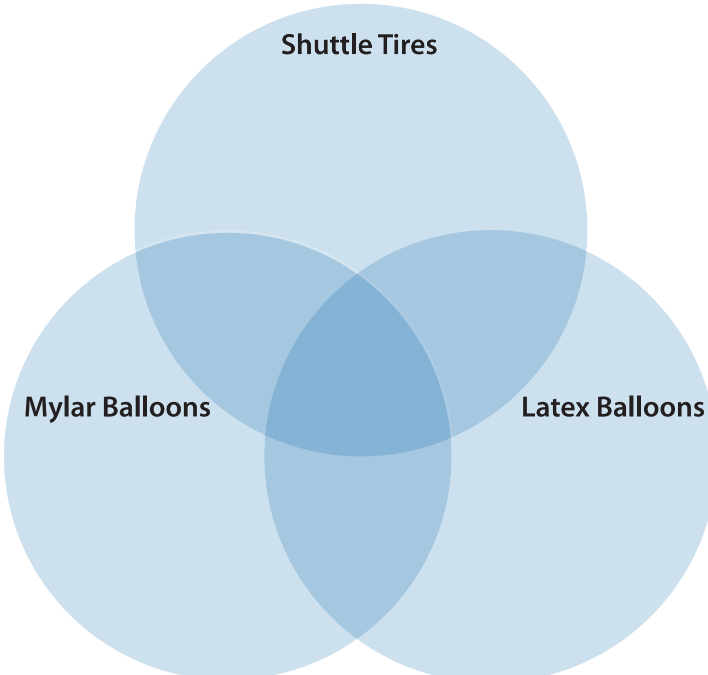
Supplemental Space Shuttle Tire Activity

Tire Permeability and Nitrogen-Filled Tires

GRADES **K–8** **5–12**

Pre-Lab Activity

Using the Venn diagram below, come up with at least two similarities and two differences between Shuttle tires, latex balloons, and Mylar balloons.



Activity

Each balloon has been filled with a different scent extract. Extracts, such as vanilla extract, are made of that specific scent and an alcohol, which vaporizes easily. The extract has vaporized inside the balloon, and if you are able to smell the extract, then the molecules of the extract vapor have been able to make their way through the pores of the balloon and to your nose.

Try to identify each of the extracts in the balloons (add more lines if necessary).

Balloon Color	Type of Balloon	Scent

Followup Questions

1. In your own words, explain why you were able to smell the extract that diffused through some of the balloons.

2. For the next question, draw pictures to explain what is happening:

Extract in a latex balloon:	Extract in a Mylar balloon:
Air inside an inflated Space Shuttle tire:	Nitrogen inside an inflated Space Shuttle tire:

3. What would be a benefit of having nitrogen in your car's tires?

4. Looking at the Mylar balloon, why do you think that Space Shuttle tires are not made of Mylar?

Supplemental Space Shuttle Tire Activity

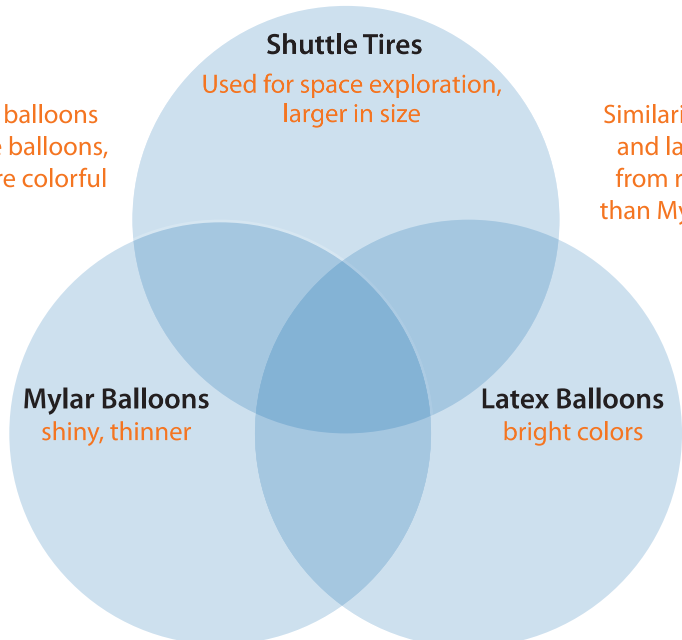
Tire Permeability and Nitrogen-Filled Tires

GRADES **K–8** **5–12** Answer Key

Pre-Lab Activity

Using the Venn diagram below, come up with at least two similarities and two differences between Shuttle tires, latex balloons, and Mylar balloons. Answers will vary but may include:

Similarities between Mylar balloons and latex balloons: both are balloons, round, used for parties, more colorful than tires



Similarities between Shuttle tires and latex balloons: both made from rubber, not shiny, heavier than Mylar, both are more porous than Mylar.

Activity

Each balloon has been filled with a different scent extract. Extracts, such as vanilla extract, are made of that specific scent and an alcohol, which vaporizes easily. The extract has vaporized inside the balloon, and if you are able to smell the extract, then the molecules of the extract vapor have been able to make their way through the pores of the balloon and to your nose.

Try to identify each of the extracts in the balloons (add more lines if necessary).

Balloon Color	Type of Balloon	Scent
This chart will depend on your choices.		

Followup Questions

1. In your own words, explain why you were able to smell the extract that diffused through some of the balloons.

Scented extract is made of tiny aromatic molecules that have been diffused in alcohol. Alcohol quickly vaporizes at room temperature, which allows the aromatics and vaporized alcohol to easily escape through the pores of a latex balloon.

2. For the next question, draw pictures to explain what is happening:

Extract in a latex balloon: Picture should show molecules escaping the balloon.	Extract in a Mylar balloon: Picture should show molecules staying inside the balloon.
Air inside an inflated Space Shuttle tire: Picture should show some molecules escaping the tire.	Nitrogen inside an inflated Space Shuttle tire: Picture should show molecules inside the tire.

3. What would be a benefit of having nitrogen in your car's tires?

Answers will vary but could include better gas mileage (since tires are properly inflated), longer tire life, greater safety since nitrogen is nonflammable.

4. Looking at the Mylar balloon, why do you think that Space Shuttle tires are not made of Mylar?

Answers will vary but could include that Mylar is too thin to make a strong enough tire.

SPACE SHUTTLE TIRES LESSONS: NATIONAL SCIENCE STANDARDS

K–12

SCIENCE AS INQUIRY
All students should develop

- Abilities necessary to do scientific inquiry

PHYSICAL SCIENCE
All students should develop an understanding of

- Properties of objects and materials

SCIENCE AND TECHNOLOGY
All students should develop

- Abilities of technological design
- Understandings about science and technology

HISTORY OF NATURE AND SCIENCE
All students should develop an understanding of

- Science as a human endeavor

5–8

SCIENCE AS INQUIRY
All students should develop

- Abilities necessary to do scientific inquiry

PHYSICAL SCIENCE
All students should develop an understanding of

- Properties and changes of properties in matter
- Motions and forces

SCIENCE AND TECHNOLOGY
All students should develop

- Abilities of technological design
- Understandings about science and technology

PERSONAL AND SOCIAL PERSPECTIVES
All students should develop an understanding of

- Science and technology in society

HISTORY AND NATURE OF SCIENCE
All students should develop an understanding of

- Science as a human endeavor

9–12

UNIFYING CONCEPTS AND PROCESSES
All students should develop an understanding of

- Systems, order, and organization

SCIENCE AND TECHNOLOGY
All students should develop

- Understandings about science and technology

PERSONAL AND SOCIAL PERSPECTIVES
All students should develop an understanding of

- Science and technology in local, national, and global challenges
- Science as a human endeavor

Aeronautics
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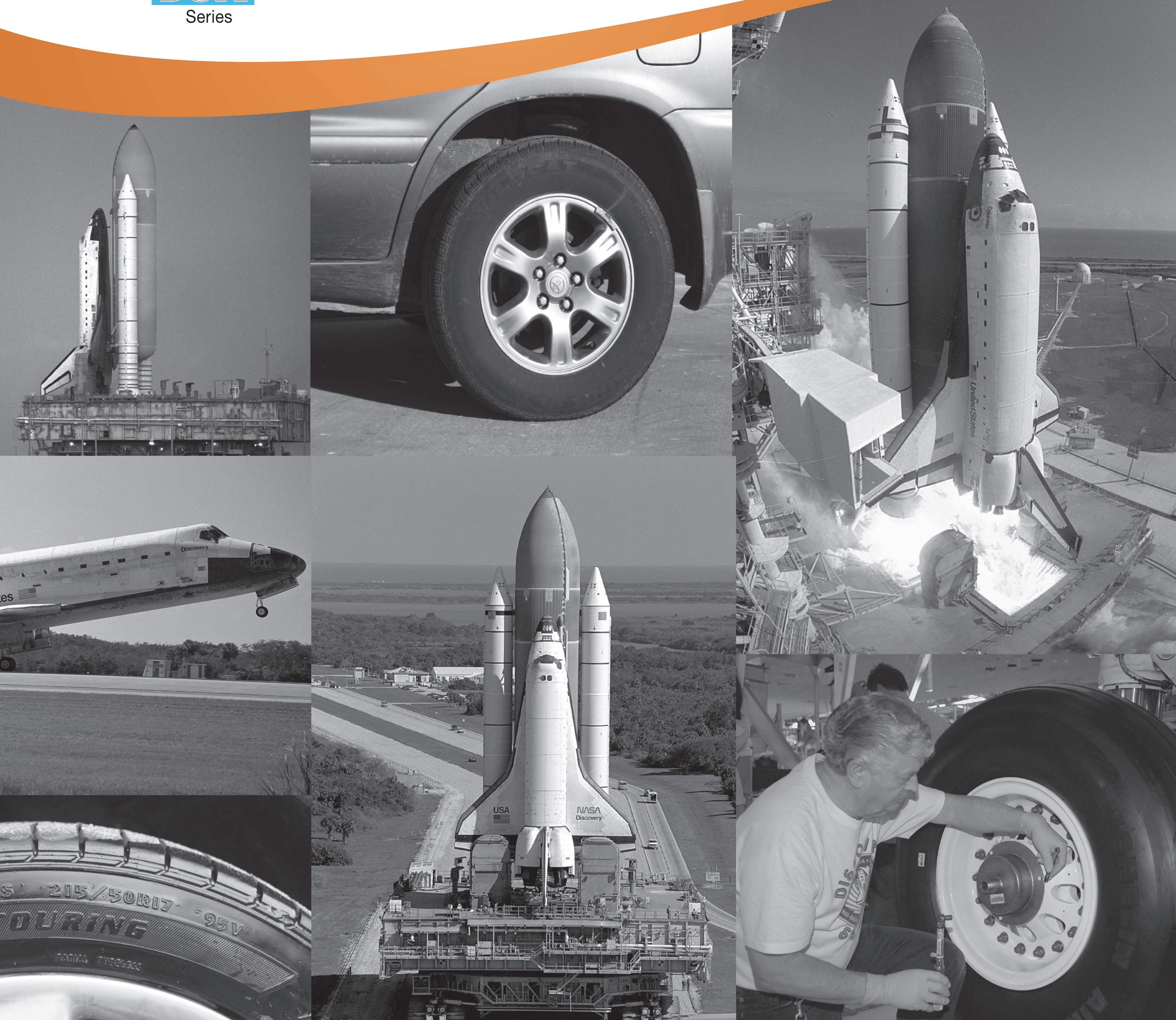
Museum in a BOX Series



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